

VIRTUELLE ARCHÄOLOGIE IN BADEN-WÜRTTEMBERG - VERARBEITUNG UND ONLINE-PRÄSENTATION VON 3D-MODELLEN

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ABSTRACT: The three-dimensional documentation has become a constantly applied technology for recording archaeological objects. Using a variety of methods, the State Office for the Preservation of Historical Monuments in Baden-Württemberg (Southwestern Germany) applies 3D scanning for the documentation, examination, and visualization of artifacts, excavated features, and sites. In addition to its scientific value, 3D models are an invaluable instrument for public outreach in order to meet the general interest in archaeological research and cultural heritage management. The specific goal of the project outlined here is the public presentation of the use of modern technology in archaeological research through the online-publication of 3D-models of archaeological objects. To enable the fluent display of these models in a web-browser, several steps of post-processing are applied, such as polygon-reduction, texture baking, and normal-mapping.

1. INTRODUCTION

Since the introduction of a constant digitization of archaeological records (illustrations, plans, maps, etc.), the documentation of artifacts, excavated features, and sites has undergone a considerable change. 3D-technology has become a routinely applied method to document, examine, and visualize archaeological objects [1]. For several years the State Office of Historical Monuments in Baden-Württemberg, Southwestern Germany (Landesamt für Denkmalpflege im Regierungspräsidium Stuttgart, abbreviated LAD), has been using different 3D scanning methods in the course of managing and documenting the state's archaeological heritage.

In recent years public interest has shown a specific focus on modern technologies applied in archaeological research. Today, the interested public is no longer satisfied with merely looking at static objects, but demands an active consumer experience [2]. Therefore, a variety of museums have installed sections in their exhibitions that illustrate current excavation and documentation techniques, the use of high-tech, and the application of various advanced scientific methods in archaeology [e.g. 3]. Besides the modern contextualized presentation of material archives and valuable "hands-on" museum exhibitions, digital 3D models

offer new ways of displaying archaeological objects. This is especially the case when 3D content can be made freely available via the internet. Exemplary pilot projects in this regard are 3D COFORM [4], 3D ICONS [5], and Smithsonian X 3D [6].

2. 3D-SCANNING IN ARCHAEOLOGICAL HERITAGE MANAGEMENT

Among the methods used by the LAD for the three-dimensional documentation of archaeological objects are terrestrial laser scanning, structured light scanning, and the SfM-method (*Structure from Motion*) [7, 8]. SfM is also used in combination with Low-altitude Aerial Photography [9]. In addition, the LAD uses data generated through airborne laser scanning for identifying and recording archaeological sites [10].

For the documentation of ongoing archaeological excavations and laboratory work on objects, four different 3D scanning devices are applied by the LAD: two laser scanners (Riegl VZ 400, Surphaser SR) and two structured light scanners (ARTEC EVA and Polygon PTM1600c). The respective equipment applied for a scan is chosen with respect to the object to be documented and the specific technological attributes of the devices. For example, while

the Riegl scanner with its long range (up to 500 m) is best suited for larger structures and features, the Surphaser scanning unit with its high precision and low measurement noise is preferred for smaller and more complex features (e.g. burials or medium-sized objects like statues). Structured light scanners are especially applied for smaller features, details of features, or artifacts.

The peculiarity of the archaeological heritage is its limited visibility, often solely during phases of excavation. Therefore, an important advantage of the use of 3D technology is the fast acquisition of high-resolution three-dimensional measurements. 3D models are then available for further post-excavation examinations and visualizations (Fig. 1). Objects can be viewed from arbitrary perspectives and it becomes possible to uncover aspects which may not even be visible in reality (Fig. 2 & 3).

2.1 BEYOND SCIENTIFIC DOCUMENTATION: PUBLIC OUTREACH AND OPEN ACCESS

In the first place, the purpose of 3D scanning techniques in archaeology is the high-precision scientific documentation of objects. Especially (2D)visualizations of 3D models from any desired perspective has been effectively used for the illustration of objects in scientific publications.

Meanwhile, 3D models have an invaluable potential for the public demonstration of archaeological objects. Ideally, 3D models of artifacts, excavated features, and sites should be viewable from arbitrary perspectives by any person and independent of high-performance computers. This can be achieved though the online-publication of 3D models, making them available via a standard web browser. This offers an excellent way to exchange and share objects, not merely between scientific institutions but especially with the interested public.

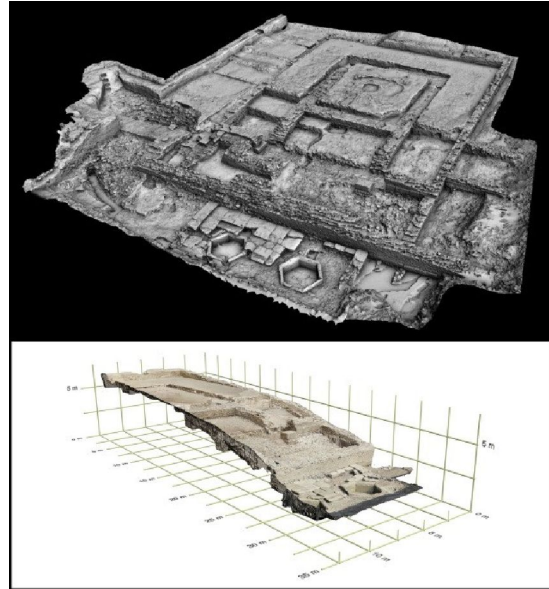


Figure 1: The detailed three-dimensional documentation enables archaeologists to visualize and examine features for post-excavation analyses, like this Roman temple in Neuenstadt am Kocher.

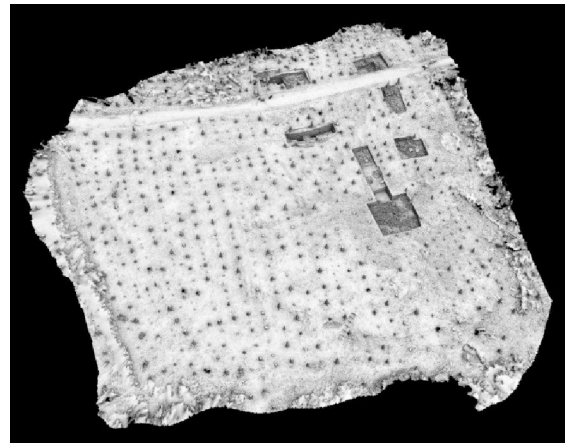


Figure 2: View on a 3D model of excavations in the Roman settlement at Hechingen. The excavated units (on the upper right) were situated in a densely forested area. The small black dots mark the trees which were also documented by the laser scanner but which were cut out in this 3D model. In this way, the actually hidden topography in the vicinity of the excavated area can be visualized.

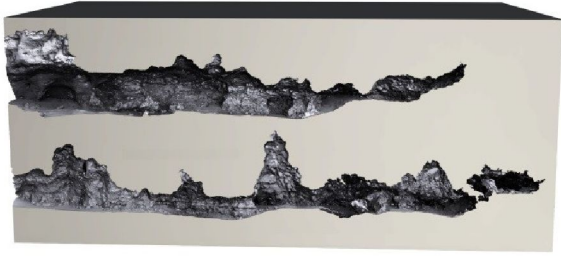


Figure 3: Longitudinal sections through the 3D model of the caves in Hohlenstein in the Swabian Jura, revealing the complex shape of these cave sites. Top: Hohlenstein-Stadel; bottom: Bärenhöhle.

The LAD therefore initiated a project to work out strategies for publishing 3D models of archaeological objects documented in southwestern Germany. The aim is to present a selection of the state's prominent archaeological heritage in a new, both informative and attractive way. Versatile 3D models, freely available online, shall work as an essential element of public outreach in order to meet the general interest in modern technology as applied in archaeological research and cultural heritage management.

2.2 POST-PROCESSING AND ONLINE-PRESENTATION OF 3D MODELS

Before the online-presentation of 3D models can be realized, the extensive amount of generated three-dimensional data must be processed. Archaeological features and artifacts are generally documented in very high resolutions, which in turn usually demands high-performance computers for processing and displaying such data. The amount of data produced during the 3D documentation is usually too large to be adequately displayed in a web browser. For example, for the documentation of the Roman temple shown in Fig. 1, ca. 110.000.000 points were measured, resulting in a filtered model with a mesh of ca. 15.000.000 triangles; the model of the menhir from Tübingen-Weilheim (Fig. 4), being a much smaller object, still consists of ca. 6.500.000 triangles (with over 50.000.000 points originally measured); the three-dimensional documentation of large structures like the caves in Hohlenstein in the Swabian Jura (Fig. 5) has even produced as many as 250.000.000 measured points resulting in models with over 30.000.000 triangles. Special software and computers with a good 3D performance are necessary to

process such data and display the respective models fluently. It is hence inevitable to optimize 3D models gained through the scientific documentation process in order to present them adequately online. Also, an appropriate 3D viewer which can be integrated in any desired website is necessary.



Figure 4: 3D model of the menhir from Tübingen-Weilheim.

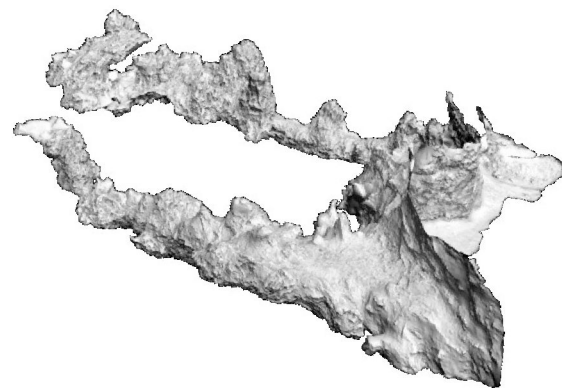


Figure 5: 3D model of the caves in "Hohlenstein" in the Swabian Jura.

In consideration of the required post-processing of our models, we found applicable examples in real-time computer graphics as applied in video games. Guided by these standards we processed our models in similar ways in a number of separate steps.

At first, the geometry of a model must be minimized. In order to obtain file sizes implementable and easy to handle in a web-context, i.e. at best not in excess of 150 MB, the reduction process must in many cases be fairly radical. This often reduces a model down to only few percent of its original size. We used software packages like Geomagic Studio and the freely available MeshLab, which offer functions to reduce the number of polygons. While the amount of data to be processed can be considerably reduced, this also strongly diminishes the overall quality of a model. Details shown in a high-res model, especially in areas with complex geometries (such as stonework, for example), are sometimes scaled down to almost unrecognizable structures (Fig. 6).



Figure 6: *The polygon-reduction of a 3D model significantly diminishes its quality, as shown by a detail view on the front part of the Roman temple of Neuenstadt am Kocher. Top: high-resolution model; bottom: low-resolution model. Note how details like the bricks of the wall in the background become blurred in the low-resolution model.*

Therefore, it is important to prevent this major loss of detail of the original object, at least in its final visualization. This is achieved by projecting attributes of a high-res model onto a reduced “copy” of this model [11]. In particular, we use normal maps in combination with “baked” textures.

Before such textures can be created, the reduced model has to be unfolded to a two-dimensional plane, the so-called UV-map. Software like the freely available Blender offer features to unfold geometries. This may be a time-consuming process. Still, even attempts to unfold extremely complex structures like the Hohlenstein-caves showed to be successful. Based on a UV-map, lighting and/or color attributes of a high-res model can be displayed on a low-res model. The high-res and the low-res models are both loaded into a single “environment” in Blender. They are scaled to equal dimensions and must be relocated to a common origin, so that they are situated at the exact same location and partly intersect each other. Now textures with attributes of the high-res model can be “baked” on the UV-map of the low-res model.

Normal maps offer the possibility to display fine-grained shading attributes. Surface normals of a 3D-model define the front- and backside of a geometry and are necessary for computing light and shading effects. To display the respective light effects on a low-res model, the normals are saved as an RGB-code in an image file based on the two-dimensional UV-map (Fig. 7). In this way, XYZ-values of the surface normals of a high-res model can be preserved, at the same time minimizing the required data volume as compared to a 3D-file format. When such a normal map is folded onto a low-res model, effects derived from the normals of the high-res model can be re-gained during rendering; thus, it is possible to preserve very fine shading effects which usually become blurred on a reduced geometry, for example a rough surface texture of a stone object.

Similarly, other shading and/or color attributes produced by special visualizations of the high-res model can be baked as a texture for the low-res model, again based on its UV-map. Especially textures baked with “ambient/reflective occlusion” [12] (Fig. 8) have provided excellent results. Through this method an idealized shading of an object independent of light sources is created. An ambient occlusion texture conveys the overall ideal shading of a high-res model despite the underlying low-res geometry (Fig. 9). In the same way, photorealistic textures of high-res models can be transferred to reduced models (Fig. 10).

Eventually, the processed low-res models with normal maps and baked textures are uploaded to an account at sketchfab.com. A Pro-account at Sketchfab allows to upload models of up to 200 MB. Sketchfab offers an integrated 3D viewer in which the models can be viewed from any perspective with different viewing options. For example, the viewing perspective can be changed between “orbit” and “first person”, the latter of which is very useful especially when viewing the inside of a model, e.g. a cave. Further, it is possible to display the wireframe of the underlying geometry in different colors. Recently, Sketchfab also introduced the new feature of annotations which is a very useful tool to better illustrate archaeological objects (Fig. 11).

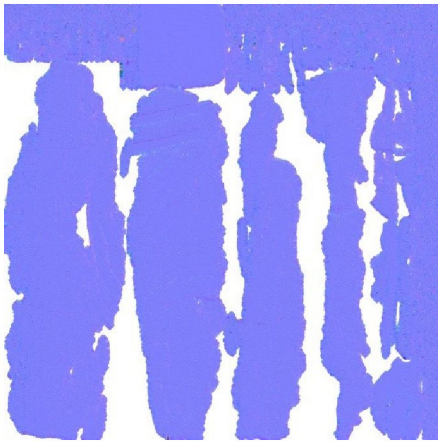


Figure 7: Normal map of the menhir of Tübingen-Weilheim.

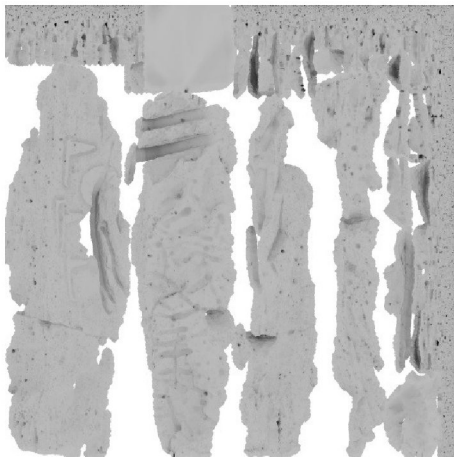


Figure 8: Ambient occlusion-texture of the menhir of Tübingen-Weilheim.

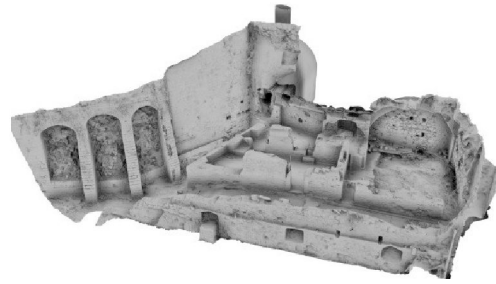


Figure 9: The 3D model of the bakery of castle „Hochburg“ near Emmendingen was significantly reduced in its geometry, but due to a normal map and an ambient occlusion texture many details of the high-res model remain visible.



Figure 10: The low-res 3D model of the celtic stele from Hirschlanden, rendered using a normal map and a color texture.

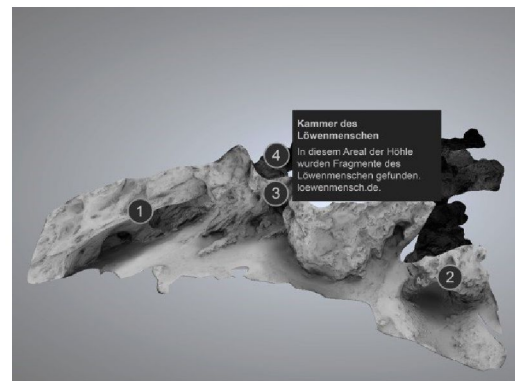


Figure 11: Front view of the caves in Hohlenstein in the Sketchfab-viewer window, with small numbers marking annotated features.

As a final step, the 3D viewer is integrated on the LAD-website, namely on the “Virtual Archaeology”-project pages. Besides general information on 3D-scanning and its application of the LAD, separate pages give specific information on the objects selected for the project. The 3D-models are incorporated on these object-specific “fact sheets” and constitute the focal point of each page (Fig. 12).

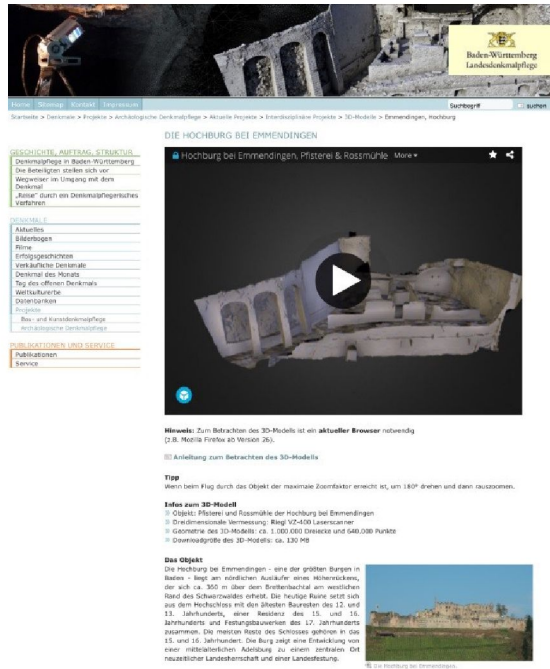


Figure 12: The “Virtual Archaeology” project website within the LAD homepage (www.denkmalpflege-bw.de) presents the 3D models as integral parts on “fact sheets” of each object.

3. CONCLUSION

The online presentation of 3D models of archaeological objects by the State Office of Historical Monuments in Baden-Württemberg is a pilot project in the German cultural resources management sector. After successfully implementing 3D technology in the scientific documentation process, it is the aim to link high-tech archaeology with public outreach, find new ways to illustrate archaeological research, and exchange information of archaeological objects through a three-dimensional visualization. In addition to the already available objects, the project-website is updated regularly with newly processed models. The

website is available on www.denkmalpflege-bw.de via “Denkmale” and “Projekte”.

4. REFERENCES

- [1] Schaich, Martin, Hightech-Vermessungstechnologien in der archäologischen Dokumentation. In: Bofinger, Jörg / Merkl, Matthias (eds.), *Mit Hightech auf den Spuren der Kelten. Begleitheft zur gleichnamigen Sonderausstellung. Archäologische Informationen aus Baden-Württemberg 61*. Landesamt für Denkmalpflege im Regierungspräsidium Stuttgart, Esslingen, 2010, pp. 99–107.
- [2] Mayer, Nina, Antike modern verpackt. Ansätze zur Vermittlung von Archäologie. In: Müller, Florian M. (ed.), *Archäologische Universitätsmuseen und -sammlungen im Spannungsfeld von Forschung, Lehre und Öffentlichkeit*. Lit Verlag, Wien/Berlin, 2013, pp. 593–606.
- [3] Mühlenbrock, Josef / Leenen, Brunhilde (eds.), *Tatort Forscherlabor. The Research Laboratory. LWL-Museum für Archäologie, Herne, 2011.*
- [4] 3D COFORM. Tools & Expertise for 3D Collection Formation. Project homepage: www.3d-coform.eu (retrieved Sept. 2014).
- [5] 3D ICONS. Project homepage: www.3dicons-project.eu (retrieved Sept. 2014).
- [6] Smithsonian X 3D. Project homepage: <http://www.3d.si.edu> (retrieved Sept. 2014).
- [7] Steffen, Markus, 3D-Laserscanning – neue Methoden zur Dokumentation und Visualisierung am Landesamt für Denkmalpflege Baden-Württemberg. In: Luhmann, Thomas / Müller, Christina (eds.), *Photogrammetrie. Laserscanning. Optische 3D-Messtechnik. Beiträge der Oldenburger 3D-Tage 2014*. Wichmann, Berlin, 2014, pp. 278–284
- [8] DeReu, Jeroen et al., Towards a three-dimensional cost-effective registration of the archaeological heritage. *Journal of Archaeological Science*, 40, 2013, pp. 1108–1121.
- [9] Bofinger, Jörg & Steffen, Christoph, Neue 3D-Dokumentationsverfahren in der Denkmalpflege – zur Verbindung von Structure From Motion (SFM) und Low-altitude Aerial Photography (LAAP). In: Luhmann, Thomas / Müller, Christina (eds.), *Photogrammetrie. Laserscanning. Optische 3D-*

Messtechnik. Beiträge der Oldenburger 3D-Tage 2014.
Wichmann, Berlin, 2014, pp. 156–163.

- [10] Bofinger, Jörg / Hesse, Ralf, Mit dem Laser durch das Blätterdach – der Einsatz von Airborne-Laserscanning zur Entdeckung von archäologischen Geländedenkmalen. In: Bofinger, Jörg / Merkl, Matthias (eds.), *Mit Hightech auf den Spuren der Kelten. Begleitheft zur gleichnamigen Sonderausstellung. Archäologische Informationen aus Baden-Württemberg 61.* Landesamt für Denkmalpflege im Regierungspräsidium Stuttgart, Esslingen, 2010, pp. 70–89.
- [11] Cignoni, P. et al., A general method for preserving attribute values on simplified meshes. In: Ebert, D. (ed.), *Visualization '98. Ninth Annual IEEE Conference on Visualization, October 18-23, 1998, Research Triangle Park, North Carolina.* IEEE Computer Society Press, Los Alamitos, pp. 59–66.
- [12] Pharr, Matt & Green, Simon, Ambient Occlusion. In: Fernando, R. (ed.), *GPU gems: programming techniques, tips, and tricks for real-time graphics,* Boston, 2004. Available from: http://http.developer.nvidia.com/GPUGems/gpugems_ch17.html (8 Jul 2014).